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SLIDE BEARING COMPOSITE MATERIAL

Description

The invention concerns a slide bearing composite material with a metallic support layer, a porous metallic carrier layer which is sintered or sprayed thereon and has a thickness of between 100 and 500μm, in particular between 200 and 350 μm, and a sliding layer which forms a sliding surface for a sliding partner and is made from a preferably lead-free sliding layer material on a polymer basis which also fills the pores of the carrier layer and optionally also comprises fillers which improve, in particular, the tribological properties. Slide bearing composite materials are continuously produced in the form of endless belts. They are divided, in particular in a longitudinal direction, into several belts and wound. The slide bearing elements are produced on the basis of a wound slide bearing composite material also using a continuous method by cutting longitudinal sections, so-called "boards", from the endless slide bearing composite material in a production machine, in particular, after edge processing such as e.g. chase threading, and are bent into a shell shape or are rolled to produce a bushing shape. A collar may thereby be additionally formed on the casing or bushing by "folding over" an edge section of the board.

Alternatively, a spherical geometrical shape may be produced from the flat board sections.

Shaping processes with slide bearing composite materials comprising a sliding layer material on a polymer basis, which is impregnated in a porous carrier layer, are always critical with regard to displacement of the sliding layer material. The sliding layer of slide bearing elements of the above-mentioned type is disposed to face the radially inward side of the

slide bearing element or the correspondingly shaped slide bearing composite material. The metallic material of the porous carrier layer and the included sliding layer material are compressed during bending or rolling of the slide bearing composite material. In contrast thereto, the radially outer side of the material of the metallic support layer is subjected to tensile stress at least on the radially outer side, i.e. outside of the so-called "neutral grain" of the shaping process. The above-mentioned compressive strain in the region of the porous carrier layer and the sliding layer material impregnated therein increase the compression among the metallic particles of the carrier layer which is disadvantageous for the porosity, i.e. the pore volume of the metallic carrier layer. Sliding layer material impregnated in the carrier layer or into its pores is thereby displaced in the direction of the surface normal of the sliding layer. This increases the wall thickness of the sliding layer material, where the sliding layer material projects past the metallic porous carrier layer. This is disadvantageous and influences the dimensional accuracy of the bent, rolled, or otherwise shaped slide bearing elements which can be produced from the slide bearing composite material.

In view of the fact that the sliding layer material should project past the carrier layer by 5 to 100 μm depending on the slide bearing element and the application, in order to form the sliding layer, the expected wall thickness increase due to shaping of the slide bearing composite material could be taken into account in the configuration of the slide bearing composite material from the beginning by reducing the projection of the sliding layer material past the carrier layer prior to shaping in correspondence with the expected wall thickness increase. It has turned out, however, that this, in turn, produces serious quality control problems due to insufficient covering of the carrier layer when the projection is initially very small. For small projections of the sliding layer material past the carrier layer, the carrier layer may disadvantageously not be completely and continuously covered or coated by the sliding layer

material, in particular due to its rough surface structure. Disturbances of this kind cannot be eliminated even through displacement of the sliding layer material in the direction of the thickness with associated wall thickness increase. One further aspect is also essential: endless slide bearing composite materials are usually produced and provided for the production of different slide bearing elements. For this reason, it would be uneconomical for certain applications to produce and provide order-related materials with small projections. Depending on the application, slide bearing composite materials with sliding layer material projecting by between 5 and 100 µm are required which should preferably be produced from the same slide bearing composite material.

It is the underlying object of the present invention to improve a slide bearing composite material of the above-mentioned type in such a fashion that a slide bearing element of high quality is produced by shaping the slide bearing composite material, thereby maintaining a good connection between the sliding layer material and the carrier layer, wherein the above-mentioned problems during shaping are eliminated or at least substantially reduced compared to prior art.

This object is achieved in accordance with the invention with a slide bearing composite material of the above-mentioned type in that the porous carrier layer is formed from spattered particles, all having a non-uniform or irregular, non-circular geometry, and a pore volume of at least 40 vol.% prior to shaping.

It has surprisingly turned that that when the porosity of the carrier layer of the initial material is relatively high, the above-described wall thickness increase during shaping of the slide bearing composite material can be reduced. This was not anticipated, since more overall material should be displaced, presumably without resistance, in a larger pore volume filled with sliding layer material. It has, however, surprisingly turned out that

this is not the case. The displacement of sliding layer material on a polymer basis of conventional slide bearing composite materials with a porous carrier layer of regular, mainly spherical, metallic particles having a porosity volume of only approximately 30% relative to the overall volume of the porous carrier layer is at least 10% higher, or even at least 20% higher, in dependence on the geometry of the shaping process. Even when the porous carrier layers are not formed from spherical particles but from round, lump-shaped or potato-shaped metallic particles (without sharp edges or deep depressions of irregular shape), which usually yields a carrier layer porosity volume of approximately 35%, the resulting wall thickness increase during shaping is disadvantageous for the above-mentioned reasons, and also problematic in view of the desired quality.

The present invention has shown that forming the carrier layer from metallic particles of a continuously irregular or non-uniform, non-circular, so-called spattered geometry which includes edged bizarre undercut sections within the carrier layer, yields a very high pore volume of at least 40 vol.%. Spattered particles have a length/width ratio of considerably more than 3, in particular considerably more than 4, in contrast to regular, spherical particles which mainly have a ratio of 1 to 1.1 and lump-shaped particles having a ratio of 1.5 to 3 but without sharp edges and with a rounded shape. The high pore volume of at least 40 vol. % that can be obtained with spattered particles in connection with the irregular, non-circular geometry of the particles of the carrier layer surprisingly causes less overall sliding layer material to be displaced from the pores of the carrier layer in a radial inward direction during shaping. This increased volume for receiving the sliding layer material can compensate for the volume reductions within the porous carrier layer caused by the shaping process, partially due to elasticity or compressibility of the sliding layer material, with the result that the latter is displaced to a lesser degree. The capacity of the porous carrier layer to retain the sliding layer material is also improved by the increased porosity

and the spattered shape of the metallic particles forming the carrier layer. The openings or channels which are open at the top and which connect the projecting sliding layer material to the carrier layer then have a larger cross-sectional surface even after the shaping process compared to porosities in the conventional range of between 30 and 35%. The irregular non-circular geometry of the spattered particles of the carrier layer which differs from the regular spherical shape or the likewise round, lump shape improves binding of the sliding layer material.

The carrier layer is preferably produced from spattered powder particles of a tin bronze alloy (CuSn8-12) having a bulk density of 2.7 to 4.2. The bulk density of a specific powder material (bulk) for filling a predetermined volume with bulk powder is defined to be a factor that, when multiplied by the mass of water which would fill the same volume, yields the mass of the powder. Filling a volume of 100 cm^3 with bulk powder yields a powder mass of 270 to 420 g. This bulk density value depends on the geometry of the powder with given alloy composition (and therefore given specific weight).

The spattered metallic powder particles which form the porous carrier layer preferably have a characteristic grain size of between 75 and 110 µm. The characteristic grain size is the value in µm which is exceeded by 50 mass % of an observed bulk and which is not exceeded 50 %. It is therefore an average particle size. The grain size distribution for a certain bulk is determined through screened refuse examination. The result can either be stated in mass % (not accumulated) for a respective mesh size or be accumulated according to DIN ISO 4497 (such that almost 100 mass % is determined for the smallest mesh size). The accumulated screened refuse can be defined using a distribution function, i.e.

$$R = e^{-\left(\frac{t}{\eta}\right)^{\beta}}$$

R = accumulated screened refuse

t = mesh size

η = characteristic grain size

β = shape parameter (slope of the straight line with logarithmic plotting according to DIN 66 145).

A preferred grain size distribution is characterized by a shape parameter β of 2.5 to 5 and a characteristic grain size in the above-stated range.

The porous carrier layer preferably has a pore volume of at least 41 %, in particular at least 42 %, in particular at least 43 %, in particular at least 44 % and preferentially of at least 45 vol. %.

It is clear that the wall thickness increase (only the increase of the projection of the sliding layer material past the porous carrier layer), depends on the wall thickness and the degree of shaping, in particular, on the diameter of a shell or bushing shape. The larger the wall thickness S_3 of a slide bearing composite material (measured across all layers) and the smaller the outer diameter of a shell or bushing shape (measured from the outer side to the outer side of the support layer), the stronger is the compressive strain and the reduction in pore volume on the inner side of the slide bearing element being produced. The increase in wall thickness a (in μm) of the sliding layer (projection past the carrier layer) of an inventive sliding layer material which is shaped into a shell or bushing satisfies the relationship

$$a = b \cdot e^{\frac{c \cdot S3}{d_2}}$$

with $0.0035 < b < 0.0045$ and $9.2 < c < 9.7$, wherein S_3 is the wall thickness of the slide bearing composite material and d_2 is the outer diameter of the bushing or shell shape.

The porosity of the porous carrier layer formed through irregular or sprayed metallic particles of irregular geometry can be calculated and stated in percent by determining the ratio of the surface portion of the pores to the overall cross-sectional surface of the porous carrier layer in a metallographic section. Towards this end, a metallographic section perpendicular to the belt plane can be produced from a slide bearing composite material after impregnation of the sliding layer material. The surface content of the bronze components shown in a cross-section is determined through scanning the periphery using a microscope. This surface content is subtracted from the overall cross-sectional surface of the carrier layer. The remaining surface then belongs to the pores and can be stated as porosity in a percentage portion relative to the overall surface. Evaluation of five different sections of the same slide bearing composite material with a separation of a few tenths of a millimeter produces sufficiently accurate values.

The sliding layer material of an inventive slide bearing composite material is advantageously based on PVDF, PES, PPS or PA. The inventive sliding layer material in accordance with one embodiment of the invention comprises at least 50 vol. % of PVDF and moreover in particular at least 60 vol. % of PVDF, in particular 60 to 85 vol. % of PVDF. In accordance with a further embodiment of the invention, it comprises at least 60 vol. % of PES or PPS, in particular 60 to 85 vol. % of PES or PPS or at least 60 vol. % of PA, in particular, 60 to 85 vol. % of PA.

Sliding layer materials on PES basis with at least 50, preferably at least 60 vol. % PES are suited for use at higher operating temperatures, in particular at long-term operating temperatures of approximately up to 140°C.

The polymeric sliding layer material may also advantageously comprise at least 5, in particular, at least 8 vol. % and also, in particular, at least 10 vol. % of PTFE. In accordance with a further embodiment of the invention, it may also be based on PTFE and comprise at least 60 vol. % and in particular at least 70 vol. % of PTFE.

The addition of PTFE as a lubricant has a significant positive effect on the tribological properties. An increasing PTFE content increases the susceptibility of the slide bearing composite material to flow erosion under extreme loads. For this reason, a slide bearing bushing with a high PTFE content or even based on PTFE basis is less suitable for shock absorber applications for bad roads (extreme load). These slide bearing bushings for shock absorber applications are therefore rather based on PVDF or PES and optionally comprise only between approximately 5 and 12 vol. % of PTFE.

The above-mentioned optional fillers may e.g. be zinc sulphide or barium sulphate with a portion of at least 5 vol. %, in particular at least 8 vol. %, and moreover, in particular, between 8 and 12 vol. % relative to the sliding layer material in the initial state.

The sliding layer material comprises at least 5 vol. %, in particular, at least 8 vol. % and moreover, in particular 8 to 12 vol. % of graphite as lubricant that improves the tribological properties.

Addition of at least 2 vol. %, in particular, 2 to 6 vol. % of carbon fibers is also advantageous to increase the loading and load-bearing capacity of the sliding layer material and the sliding layer formed therefrom.

The porous carrier layer is preferably formed from tin bronze particles, in particular of CuSn (8-12) particles. The support layer of the sliding layer composite material may consist of steel or bronze.

The present invention also concerns a slide bearing bushing produced from a slide bearing composite material according to one or more of the claims 1 through 19. The invention also concerns a slide bearing bushing for shock absorber applications comprising the features of claim 20.

Further features, details and advantages of the invention can be extracted from the enclosed claims and the drawing and the following description of preferred embodiments of the inventive slide bearing composite material.

Fig. 1 shows a schematic sectional view through an inventive slide bearing composite material; and

Fig. 2 shows the determined wall thickness increase in dependence on the ratio between the wall thickness of the slide bearing composite material and the bushing diameter.

Fig. 1 shows a slide bearing composite material, designated in total with reference numeral 2, comprising a metallic support layer 4 of steel and a metallic porous carrier layer 6 which defines a pore volume relative to the volume of the carrier layer of at least 40 vol. %. One can also see the sliding layer material 8 on a polymer basis which not only preferably completely fills the pores of the carrier layer 6 but also forms a projection past the porous carrier layer 6 to form the sliding layer 10. The sliding layer 10 or the sliding layer material 8 forming the sliding layer 10 must completely cover the carrier layer 6 to an optimum extent without producing cracks, gaps or openings on the surface. The porous carrier layer should be covered to preferably 100 % already in the initial state of the slide bearing composite material, i.e. prior to shaping to form sliding elements.

Preferred compositions of the lead-free sliding layer material are given below:

1. PA 67 vol. %
   PTFE 10 vol. %
   ZnS 10 vol. %
   Graphite 10 vol. %
   C fibers 3 vol. %

2. PVDF 67 vol. %
   PTFE 10 vol. %
   ZnS 10 vol. %
   Graphite 10 vol. %
   C fibers 3 vol. %

3. PVDF 67 vol. %
   PTFE 10 vol. %
   $BaSO_4$ 10 vol. %
   Graphite 10 vol. %
   C fibers 3 vol. %

4. PES 70 vol. %
   PTFE 10 vol. %
   PPSU 10 vol. %
   $BaSO_4$ 5 vol. %
   TiO_2 5 vol. %

5. PPS 70 vol. %
   PTFE 10 vol. %
   PPSU 10 vol. %
   $BaSO_4$ 5 vol. %
   TiO_2 5 vol. %

6. PTFE 75 vol. %
   ZnS 17 vol. %
   PFA 5 vol. %
   C fibers 3 vol. %

The wall thickness increase a in Fig. 2 in dependence on the ratio (S_3/d_2) (wall thickness of the slide bearing composite material / outer diameter of a bushing rolled therefrom) was determined for two slide bearing composite materials which have different porosity volumes, 28 vol. % and 45 vol. %. The slide bearing composite material comprises a support layer of steel, a porous sintered carrier layer of spherical CuSn10 bronze particles (28 vol. %) and spattered CuSn10 bronze particles (45 vol. %) which was filled with a sliding layer based on PTFE.

The ratio S_3/d_2 in a slide bearing bushing rolled from this slide bearing composite material having an inner diameter of 11mm and a slide bearing composite material wall thickness of 1mm is 0.091. The curves of Fig. 2 show a difference in wall thickness increase of approximately 2 µm, i.e. a difference on the order of magnitude of approximately 20 % of the tested materials.